1 Introduction[1]

This chapter presents the background of a study performed for the U.S. Army Engineer District, Seattle, to determine the technical feasibility of maintaining a reliable bar navigation channel into Willapa Bay, Washington. The study was authorized by the Seattle District in cooperation with the Port of Willapa Harbor under a Partnering Agreement. The study was conducted primarily by staff of the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory. Field data were collected by Evans-Hamilton, Inc. (EHI), and its subcontractor, Pacific International Engineering^{PLLC} (PIE), which is conducting independent field and analytical studies for the State Route 105 (SR-105) project at Willapa Bay (PIE 1997). Included in this chapter are overviews of the study site and discussions of related studies at Willapa Bay, study procedure, and scope of this report.

Background

Willapa Bay is a large estuarine system located on the southwest Washington coast, as shown in Figure 1-1. Its spring or diurnal range tidal prism, compiled from other sources by Jarrett (1976) at more than 10^{10} cu ft,[2] is one of the largest of all inlets on the coast of the continental United States. The magnitude of the tidal prism is produced by the broad bay area and relatively large tidal range at the site. The tidal range at the entrance to Willapa Bay, as measured by the National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration, is approximately 7 ft. Daily wind speed is moderate, and river inflows do not contribute significantly to the flow through the entrance. Bay hydrodynamic processes are discussed further in Chapters 2 and 6.

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[2] A table for converting non-SI units to SI units of measure is given on page xix.

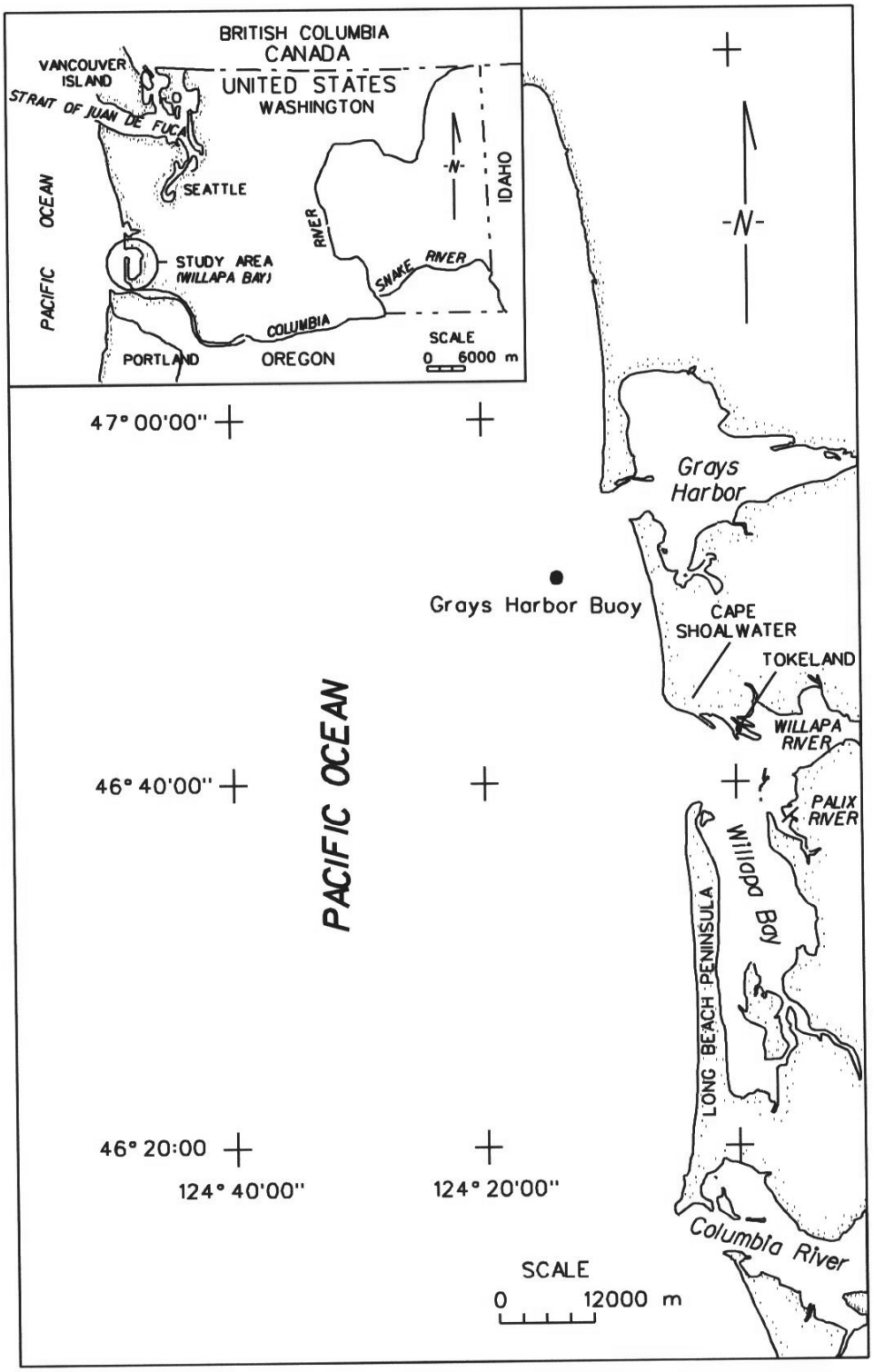

Figure 1-1. Regional location map for Willapa Bay, Washington

A wave hindcast covering 20 years (Jensen, Hubertz, and Payne 1990) predicted a mean significant wave height of 7.7 ft and a mean spectral period of 11 sec at hindcast Station 18 located in water depth of 33 ft in the vicinity of Willapa Bay. The largest wave in the hindcast had a height of 23.8 ft. Ruggierio et al. (1997) discusses the extreme waves and water levels along this coast during the 1997-1998 El Niño. Measurements made during the past 3 years at a nearshore wave buoy located south of Grays Harbor, as well as limited measurements of the waves at the entrance to Willapa Bay made in this study, confirm the magnitudes given by the hindcast. Properties of waves incident to the Willapa Bay entrance are discussed in Chapter 5, where numerical simulations of waves propagating into the bay are described. Wave measurements made in this study are described in Chapter 4.

The large tidal prism and energetic waves at Willapa Bay collectively act to transport millions of cubic yards of sediment on this predominantly sandy coast. The massive changes in shoals at the Willapa Bay entrance are discussed in Chapter 4. Neighboring bar entrances, such as Grays Harbor, the mouth of the Columbia River, and entrances along the coasts of Oregon and northern California are protected by jetties that are miles long. Construction of jetties improves navigation by stabilizing the position of the channel, focusing the tidal flow to clear sediment from the channel, and protecting vessels from waves as they transit through the surf zone.

The conception of a navigable channel at a wide and energetic inlet may seem improbable at first. However, information compiled in Chapter 3 shows that a natural but mobile channel some 25 ft deep typically penetrates the outer and middle entrance bars. The tidal prism at Willapa Bay maintains a dynamically stable channel cross section that usually contains a channel approaching design requirements. Inlet stability and bulk characteristics of the entrance, as well as details of the Federal navigation channel at the entrance, are discussed in Chapter 2.

Authorizations for a Federal navigation channel through the entrance to Willapa Bay are summarized in U.S. Army Engineer District, Seattle (1971), and in Chapter 2. The existing project was first adopted in 1916 and last modified through authorization in 1954. The authorization provides for a channel over the bar of the mouth of Willapa Bay to be 26 ft deep, measured to mean lower low water (mllw), and at least 500 ft wide. A bar channel of this dimension is required for existing shallow-draft commerce. Dredging of the deep-draft river channel of Willapa Harbor was discontinued by the Seattle District in 1976 because of inadequate benefits. Dredging for shallow draft continues at Willapa Harbor for facilities at such locations as Toke Point, Bay Center, and Nahcotta, shown in Figure 1-2. Since 1976, no maintenance dredging has been required along the Federal river channel leading up from Willapa Bay to port facilities located at Raymond, Washington.

The Washington Department of Transportation (WDOT) has recently constructed a groin and dike in the North (ebb) Channel at the entrance to Willapa Bay to protect SR-105. The adjacent shoreline (Cape Shoalwater) had been eroding at a rate of approximately 130 ft/year (Terich and Levenseller 1986; Komar 1998), and the erosion had endangered the State highway. The dike and groin are expected to significantly alter the flow and, possibly, the location and

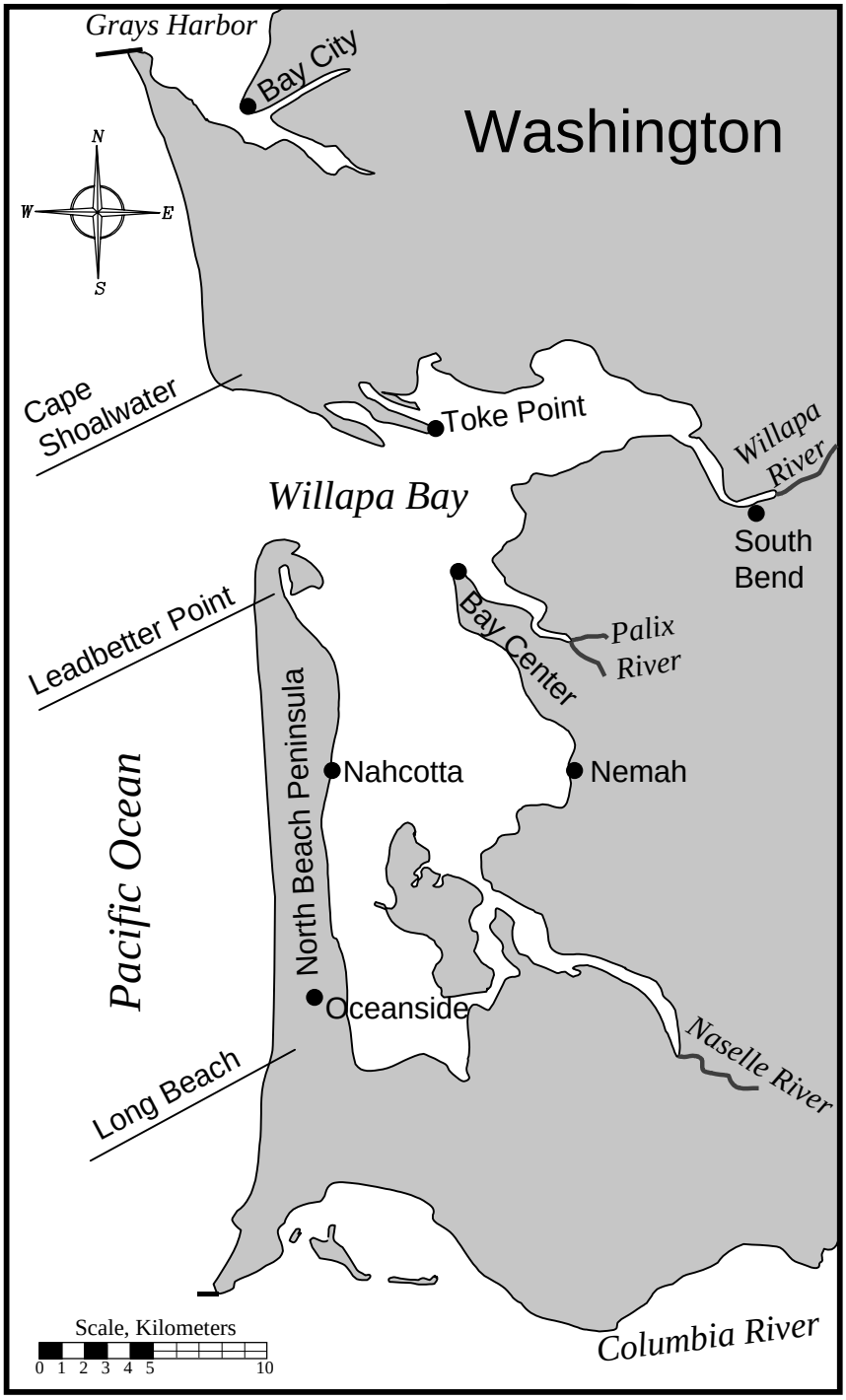

Figure 1-2. Willapa Bay and adjacent communities

stability of the North Channel. Action of the WDOT Cape Shoalwater shore protection project was considered in the channel stability analysis phase of the study.

Purpose of Study

The shifting channels at the entrance to Willapa Bay make bar navigation unreliable (U.S. Army Engineer District, Seattle 1971, 1995), and the local port cannot maintain or attract commercial users. Local interests have obtained Congressional support to determine if an economical channel can be established through the entrance bar. An economical channel implies a route that can be traversed safely under typical waves and tidal currents.

The Seattle District requested the U.S. Army Engineer Research and Development Center (ERDC) to conduct a study to determine the technical feasibility of maintaining a reliable channel (28-ft depth including advance dredging and overdredging allowance) over the entrance bar and into Willapa Bay. "Channel reliability" refers to stability of location and depth of the channel for an acceptable construction and maintenance cost, as well as hydrodynamic conditions for safe passage.

Ebb currents exiting the southern arm of Willapa Bay (the arm extending toward Oceanside) are directed toward the landmass of Cape Shoalwater, where they turn and run west in a relatively deep North Channel. Water exiting the tidal flats along the Willapa River also tends to flow out of the North Channel. Other channels through the bar exist ephemerally, including a Middle Channel and a South Channel, sometimes called the Leadbetter Channel in the literature. The typical locations of these channels are shown schematically in Figure 1-3. Multiple bar channels through the entrance sometimes exist, but typically one channel dominates. Properties of the natural channels, including location, persistence, and depth, are discussed in Chapter 3, based on an extensive record of bathymetry surveys spanning more than a century. The presence of these channels and their possible exploitation as a navigation channel form the basis for developing channel design alternatives, as described in Chapter 2.

Related Studies

The State of Washington is conducting two studies of coastal and inlet processes of interest to the present proposed effort. The Washington Department of Ecology (WDOE), in a joint study with the U.S. Geological Survey, is making a regional coastal assessment that includes analysis of all available historic and present data on shoreline position and bathymetry (Gelfenbaum et al. 1997; Kaminsky et al. 1999).

The WDOT, through its lead contractor, PIE, and PIE subcontractor, EHI, is collecting data on waves and currents at the entrance and is monitoring coastal and inlet processes for the SR-105 Cape Shoalwater shore protection project (PIE 1997). PIE has also conducted a morphological analysis of bar channel migration, based on earlier work by the Seattle District and others. The NOS maintains a long-term water-level station in Willapa Bay at Toke Point. As much as possible within study constraints, all relevant data were considered and joint

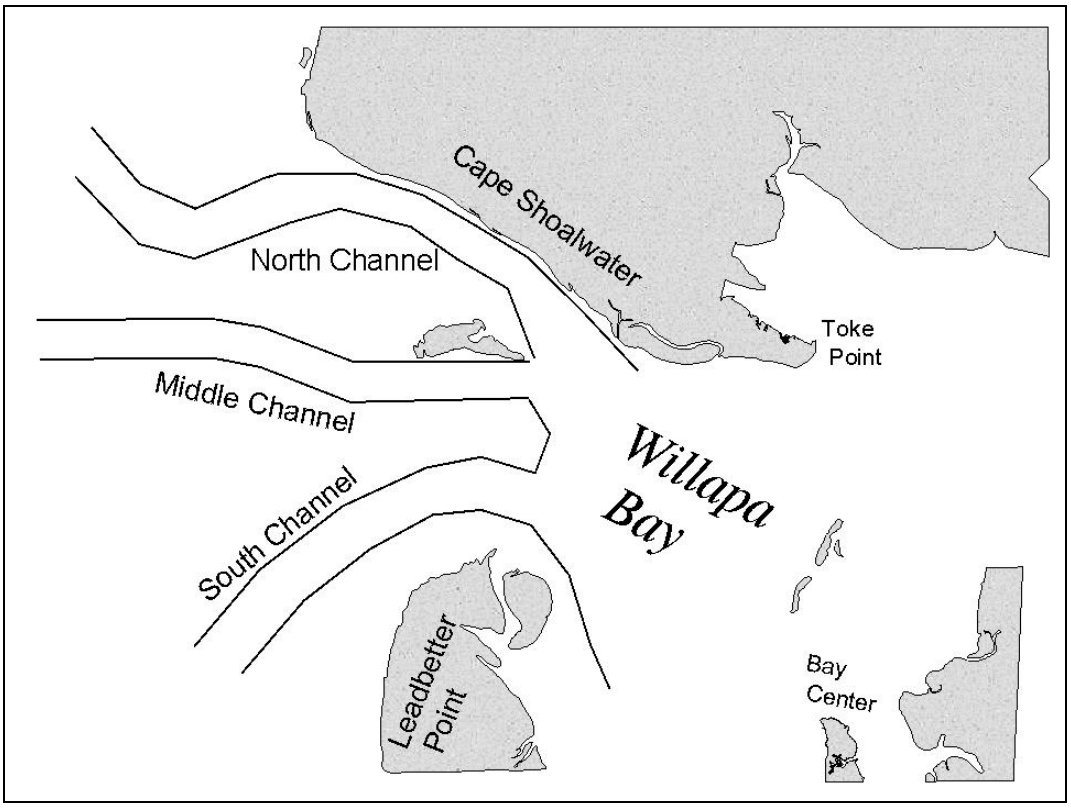

Figure 1-3. General locations and orientations of natural entrance channels to Willapa Bay

and coordinated efforts made with these agencies and organizations, including the University of Washington, for efficient and cost-effective conduct of this study.

Study Procedure

The study required focused efforts of several specialists who participated as a team in developing approaches and procedures and in conducting the required work. Meetings and briefings were held at the study site and at the Seattle District, as well as at ERDC, with participation from the Port of Willapa, WDOE, PIE (representing local interests), EHI, Seattle District, and ERDC. ERDC investigators also toured the study site, made reconnaissance trips for locating instruments in and around Willapa Bay, and participated in data collection.

The study was developed as a simultaneous effort in two major tasks. One task involved analytical and numerical studies covering the following:

a. Engineering activities in consideration of entrance channel alternatives and their relation to maintenance and operation of a navigable channel.

b. Formulation of alternative designs for a reliable bar navigation channel.

c. Analysis and interpretation of inlet morphology change.

d. Numerical modeling and associated analyses of wave transformation at the entrance, circulation and water level throughout the bay, transport of sediment at the entrance, and salinity distribution in the bay.

The other task involved sustained data collection and analysis in support of the analytical and numerical efforts, as well as documentation of the background condition of waves, wind, current, and morphology at the entrance, and water level and salinity around the perimeter of the bay. A survey of the discharge and salinity within the bay was made by two boats. Bathymetry data, the most basic information upon which most of the study components depend, were collected by the Corps' airborne laser system and by a considerable dedicated effort of the Seattle District's main survey boat, the *Shoalhunter*.

The Seattle District requested preliminary study results by 1 February 1999, which required rapid planning and mobilization to deploy instruments in the severe environment of the entrance to Willapa Bay and along the substantial perimeter of the bay. Authorization to proceed was received in April 1998, and a data collection plan was developed and instruments procured and leased for gradual deployment commencing in July 1998. Data were downloaded in a series of instrument servicing trips and subsequently quality checked and reduced expediently for distribution to the analytical and numerical components of the study. The difficult but successful field data collection program is described in Chapter 4.

An interim copy of this report was transmitted to the Seattle District on 21 December 1998 for review and discussion by the District and local interests. Further study was then conducted, leading to this final report.

Scope of Report

This report documents the procedures, results, and conclusions of the subject study. Study team members described their work in individual chapters. The chapters were planned to form a coherent approach in meeting the study objective of determining the feasibility of a reliable bar navigation channel into Willapa Bay. The approach and content of all chapters were coordinated, and an attempt was made to provide sufficient background information and cross-referencing to allow each chapter to stand alone with regard to its particular subject matter.

Chapter 2 documents the Federal navigation project at Willapa Bay and describes approaches to investigating channel reliability in a natural inlet. Chapter 3 presents results of a morphology analysis based primarily on surveys of the bathymetry spanning more than a century. Chapter 4 summarizes the field data collection program and general properties of the data sets. Chapter 5 presents results of short wave numerical simulations. Chapter 6 presents analysis of tidal circulation, sediment transport, and salinity change. Chapter 7 discusses the channel alternative designs considered through the report. Appendices A-H contain supplementary and background information.

Units of Measurement

Dimensions and quantities originally reported in American Customary (non-SI) units on engineering documents and in the literature are retained. A table of conversion factors from non-SI to SI units is given on page xix. Oceanographic and meteorologic measurements and calculations, such as of waves, water current, and wind speed are given in SI units.

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